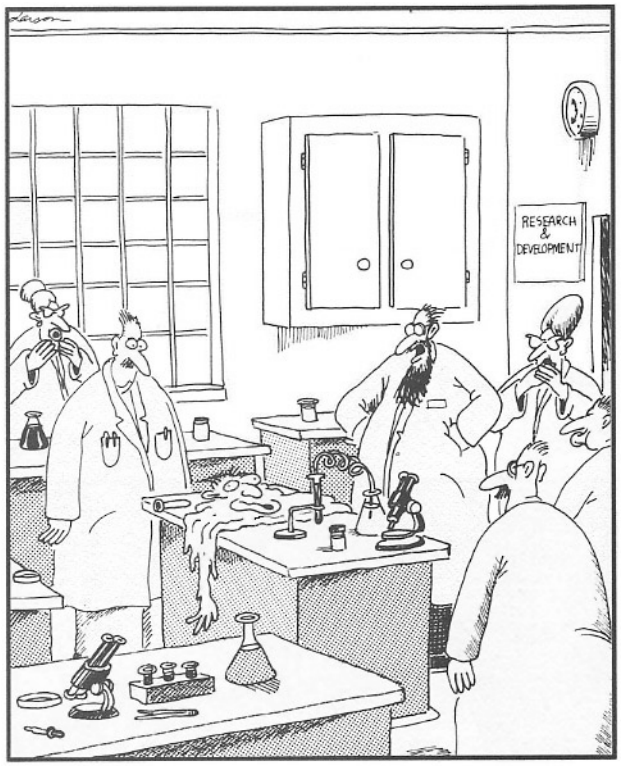
University of Manitoba

Nano-Systems Fabrication Laboratory

Cleanroom Users Manual

Respectfully modified from Gary Larson's "The Far Side"



"My God! It is Professor Shafai! . . . Buchanan, see if you can make out what the devil he was working on, and the rest of you get back to your stations."

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Nano-Systems Fabrication Laboratory

ACKNOWLEDGEMENTS

Though this manual is for the use of all, it is copyrighted. If you use sections of it in your work, please reference it as "The Nano-Systems Fabrication Laboratory Cleanroom Users Manual", University of Manitoba. It was written by Lianne Lester with suggestions of content and layout from the cleanroom manuals of Georgia Tech, Stanford, MIT, Carnegie Mellon, Cornell, UCLA- Berkeley, and the University of Alberta, as well as comments from Cyrus Shafai, Doug Buchanan, and Derek Oliver

INTRODUCTION

The Nano Systems Fabrication Laboratory (NSFL) is a place where people from many different educational backgrounds and research interests come to explore the possibilities of construction on the infinitesimal scale to merely the very tiny. Scientists doing pure research may work next to industrialists developing their most advanced product line.

We have designed this program for the work to be harmonious and productive, and to ensure the safety of all laboratory users. It is based on the requirements outlined in the safety policy of the University, (Controlled Products Standard), Province (Workplace Health and Safety Act -W210), and Country. (WHMIS, Occupational Health and Safety Act)

As with any policy, the overall success is determined by the desire on the part of participants to follow it. We hope the following pages will provide enough information so that the necessity of obeying the rules becomes self-evident. Entry into the Lab exposes users to the dangers inherent in any workplace where extremely hazardous chemicals and high temperature equipment is in use. When everyone understands and follows the policy, nobody dies.

In this vein, here are some "common sense" ideas.

Ask questions

There are no questions too stupid or simple to ask; only differing degrees of misfortune when they go unanswered. We trust people who ask questions more than those that don't, because questions provide us with a window into how a mind is operating. It allows us to monitor if you actually understand what we are teaching.

Ask questions when equipment is not operating as expected. Ask questions if you have been out of the lab for a while, and things are a bit fuzzy. Ask questions when your supervisor is training you, because theoretical knowledge is different then knowledge gained by real-life practice.

Don't work if you are tired

Much of what makes a micromachined or microelectronic device a success is exactness of placement (litho), or timing (etches). Inattention equals a poor or a wrecked device. Accidents are more likely when you are tired. When things go wrong, you are less likely to handle the situation well.

Don't work if you are sick

A single cough generates 6 million particles, <0.5μm in size, and projects them 1 metre. A sneeze can have 20 million particles, and ejects them at 200 miles per hour, traveling 3 - 4.5 m. Because of the particulates generated by coughing/sneezing, no one with an active cold or allergy is permitted in the cleanroom.

ACCESS

To gain admission to the NSFL, all individuals must:

1) Read the introduction book and demonstrate comprehension by passing a test.

2) Sign a release form agreeing to abide by the policies set out in the users manual.

3) Learn the location of emergency exits, fire extinguishers, first aid kits and chemical accident showers by "filling in the blanks" of the lab map.

4) Complete the "who are you, who is your supervisor, what is your tentative project" form.

5) Buy the lab material package containing your very own pair of chemical processing gloves, mandatory safety glasses, teflon coated wafer tweezers (your choice of size), cleanroom notebook, and storage bin. These items will be stored on the metal shelves in the inspection hallway of the cleanroom. Occasional users (less than three visits per month) can choose to use the spare items provided by the Lab.

Normal hours

Room E3-450 is open to all users from 9:00 am to 4:30 pm. As you enter the lab, check the booking sheets to see if the equipment you want to use is free. If the time slot is empty, book the equipment for up to three hours by writing in your name AND the process you will be running. Advance booking equipment is allowed, but:

- the same piece of equipment/processing area can be advance booked only once per day. At the end of your allotted time slot, you can re-check the sign-up sheets, and if no other user has booked the equipment/process area, you can re-book for up to another three hours. As a courtesy to the other uses, only book in for the time you are actually going to use.

- You will lose the slot if you are more than 15 minutes late.

Put your ID/Access card in the slot board, then put on the available shoe covers. The ID board exists for a few reasons. If there has been an accident, the hazard response team has a way of estimating the number of people involved. It is also the way users can monitor the number of people in the cleanroom to ensure they are not breaking the "safety buddy" rule.

Safety Buddy

1) Normal hours

If you don't have a buddy, don't work. They are the people who help you to the safety shower when a chemical splashes into your eyes. They are the ones who warn other users away while you notify a staff member of a hazard you have created. Your buddy should:

- Know what you are doing and when you are doing it.
- Be within 10 feet of you if you are using HF or BOE.
- Be in the cleanroom or chase during other processing activities (not necessarily in the immediate area) and check in on you every 30 minutes
- Know what to do in case of an emergency.

(based on Carnegie/Mellon University's "Nanofabrication Facility Guidelines 2002")

During normal working hours, you can find out how many people are in the lab by checking the ID board. Talk to one of them, and agree to be "buddies". When leaving the lab, notify your buddy so a new arrangement can be made. If you are the second last person out of the lab for lunch or the day, it is your responsibility to notify the last person and wait for them. It is the last person's responsibility to leave as soon as possible. As long as you are not wet chemical processing, you can work in room E3-450 alone, providing that you and your buddy have filled out the "Safety Buddy sign-up" sheet on the wall.

2) After hours

This policy applies only to qualified users of the machines involved who also have 24 hr lab access. Apprentice users or those with restricted lab access are expected to use the facility during normal hours of operation.

Lab activities have been divided into 3 categories.

No after hours activity permitted:

- PECVD
- Pyrogenic oxidation using LTO high temperature tubes

Safety buddy must be WITH YOU IN THE ROOM during the activity:

- HF and BOE solutions
- Hot piranha solutions (both acid and base types)
- Metal etches (Cr, Al, Au, Ti)
- Silicon etches (KOH, TMAH, EDP)
- Equipment repair in high voltage areas

Safety buddy checks in on you every 30 minutes (within-building phone checks permitted):

- Sputter system or thermal evaporator repair / maintenance / use
- RIE (standard processes only)
- XeF_2
- Laser usage
- Litho (standard photoresists; spinning, expose, develop)
- High temperature ovens (standard oxidations and anneals)
- Wafer saw

Guests and outside contractors

Since each person walking in the lab generates between 2 to 5 million 0.5μm particles per minute, only essential personal should be in the cleanroom. Visitors can view most of the processing areas from the chase, and lab tours from the chase area are permitted as long as verbal approval from the Director, Supervisor, or lab staff has been obtained. If someone MUST enter the cleanroom, 24 hour written notice must be given to the Supervisory Committee, and the Visitor Access Form must be completed.

Why how you dress and behave matters

This is important so your project doesn't develop the "killer defects" caused by particles and oil films. Particles are released every minute by:

1) People
   We renew our outer layer of skin every 4 days. The amount of particles larger than 0.5μm shed every minute depends on activity. Sitting motionless generates 100,000, getting up 2.5 million, moving slowly and conservatively 5 million, goofing off 30 to 100 million. (From "Introduction to Contamination Control and Cleanroom Technology" by Matts Ramstorp)

2) Things
   Paper, cardboard, rubber, wood, pencils

3) Processes
   RIE, sputter system, wafer saw, thermal evaporator

Organic films as thin as 10nm will cause devices to perish. They block adhesion for metal lines and photoresist. Films are deposited by finger oils, and outgassing solvents from photoresist, cologne, and antiperspirant ... If it smells, it's wafting around big organic molecules.

The cleanroom gowning and behavior rules are designed to minimize the contamination inputs we can control. With the HEPA filtration system and these rules, we hope to achieve "class 10" (10 particles 0.5 microns or larger per cubic foot) in the cleanroom, a vastly different amount than that found in the Engineering building. (Typically 1 million particles per cubic foot)

Preparation for gowning

1) Although it should be completely obvious, NO FOOD OR DRINK in the Fab.
2) Your clothes should be freshly laundered; you should be recently bathed.
3) No make-up. No powder. No colognes.
4) Indoor shoes (clean) which are flat-bottomed and stable must be worn. The only sandals permitted are the "hiking" variety. (no heels, no strapless, no "flip flops")
5) Before you enter the lab, tie up long hair so it fits under the caps more easily.
6) Remove rings and watches. (These trap chemicals and tear gloves. If you have a strong personal attachment, for example to a wedding ring, please consent to wear it in your pocket or on a chain under your clothes.)
7) Anything brought into the cleanroom must be compatible, and properly cleaned. The particles on most items are removed by wiping the surface with isopropyl alcohol on a cleanroom wipe. These can be found in the chase on the table beside the pass-through for the spare module. Very dirty items should be vacuumed, washed with a dilute liquid soap, and rinsed several times with DI before the IPA particulate wipedown. After the item is cleaned, use the spare module's door or pass-through to bring it into the lab.

How to gown for the cleanroom

1) You already have your shoe covers on. (You put them on when you entered the room, right?) Enter gowning.
2) Check your bunnysuit for holes and seam separations. Particles will shoot out from these locations like geysers every time you move (the suit acts like a bellow). If the suit is damaged, inform the lab staff and take another.
3) Get a hair cap from the box and put it on. All of the hair and ears should be covered.
4) Put the hood on over the hair cap. The snap-in mask should be over your nose.
5) Put on the coveralls, one leg at a time WHILE HOLDING THE ARMS AND BODY OF THE SUIT UP OFF THE FLOOR. The hood should be tucked in, and the coverall zipped to the neck.
6) Walk over to the bins with the overboots, and retrieve the correct size. Ideally, the only surface the sole should touch is the sticky mat in front of the airshower and the floor inside the cleanroom. If this isn't possible, step several times on the sticky mat to remove the extra dirt.

7) Everyone in the Fab must wear safety glasses. Visitors and infrequent users will find safety glasses (small, large) in the bins in gowning. Regular users will have their own. (All glasses should be cleaned with an IPA wipe before re-entering the cleanroom)

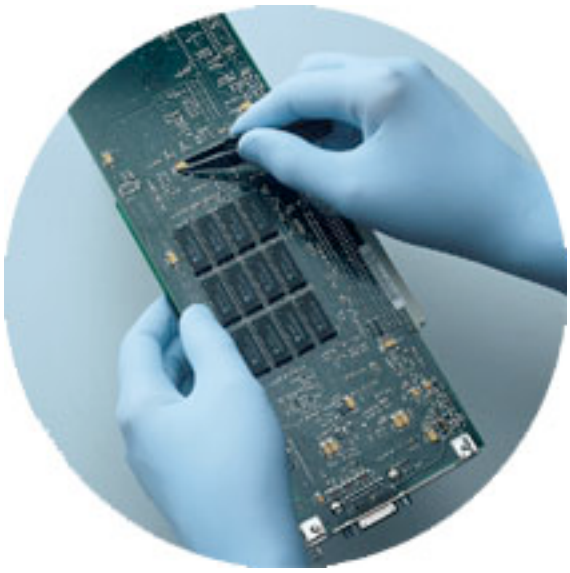
   - Safety glasses can be removed in Litho and Inspection rooms while using the microscopes. If you keep them in your lap while you are sitting down, you will be reminded to put them back on when you get up.

   - Goggles offer better protection against chemical splashes than glasses. There are several pairs in gowning for anyone who wishes this extra level of protection while doing chemical processing.

   - Prescription eyeglasses will only be considered as alternatives to safety glasses if they have polycarbonate lenses, side shields, and approval from the safety committee.

   Note - Safety glasses must also be worn in the chase area around the wafer saw, oxidation oven. There is the possibility of eye damage due to particles in these areas.

8) Put on nitrile gloves from the appropriate bin. (small, medium, large). Properly fitting gloves look like this:



They have no edges to catch on tools, machines, or substrates, and no wrinkles where hazardous chemicals stay trapped after you think the gloves have been properly rinsed.

Because space in gowning is very constricted, only 2 people can gown or de-gown at the same time. De-gowning just reverses the gowning order. Gloves off, glasses off, overboots off and back in proper

bins, coverall off, hood off (snap hood to coverall neck), hair cap off (can be kept inside hood). Take the overshoes off before you leave the room, and REMEMBER TO PICK UP YOUR ID CARD.

Cleanroom compatible:

- items with smooth, non-particulating surfaces which can be wiped down with IPA
- paper and lab books made for cleanrooms out of polymer impregnated paper
- dust-free (non-clicking) pens. i.e. ballpoint and felt pens
- walking slowly
- changing or cleaning gloves whenever they get dirty or torn

Not cleanroom compatible:

- sunburns
- pencils, erasers
- gum, food, drinks
- make-up, hairspray
- cardboard, Styrofoam
- leaning against equipment or wet decks
- smoking less than 1 hour before working
- oily residue on new items (such as wafer tweezers) from manufacturing processes
- putting something dirty (e.g. -you) between your device and the clean air source

Common Mistakes:

- touching face or hands with gloves
- keeping face mask below nose
- using tools which have fallen on the floor without cleaning them
- not changing/cleaning gloves when a questionable surface has been touched
- picking up gloves by the fingers instead of the wrist when gowning
- bringing in tools to the cleanroom without cleaning them (often pens)

(From "Class 100,000 Cleanroom Operations Training Course Outline" by Nick Virmani)

Coughing note: To minimize the impact of the occasional, unavoidable cough, leave the cleanroom and go into a less sensitive area like gowning. If this isn't possible, turn away from the production area and cough into a cleanroom wipe. Dispose of wipe in the garbage, and put on fresh gloves, or clean your gloves thoroughly with IPA.

TRAINING

Initial

Read the appropriate background materials. For example, if you want to be trained in Lithography, you would read the appropriate section from a semiconductor processing textbook. You would also look up the MSDS (chemical information sheets) for the photoresists and developers used by the lab.

Apprentice User

A qualified user will be assigned to train you. You will receive a booklet on the information and experience necessary to become a qualified user of the specific process/piece of equipment. The booklet provides an outline for study, as well as a checklist to document your progress. The amount of time in the apprentice user stage depends on the equipment/process being learned and your own application.

Initially, you may only use equipment under the direct supervision of the person assigned to train you. Only "standard" equipment functions or process recipes may be used. After several run-throughs of the process, when you have demonstrated the ability to run the equipment independently and to recognize when the equipment isn't working as expected, your supervisor may decide you need only ask permission to use the equipment. Please note however, only a qualified user (i.e. your supervisor) can book equipment. It is hoped this inconvenience will provide the necessary impetus for you to complete the requirements for qualified user status. And as a note to supervisors, you are responsible for any action taken by your assigned apprentice. This should ensure proper training.

Qualified User

A person becomes a qualified user after completing the checklist in the booklet, and passing any associated test. You may book and use the equipment/processes you have trained on without supervision. As to modifications of equipment/processes, please read the following quote.

> "There are lots of chemical users in Silicon Valley who are not chemists, and they tend to spill things. There are also some engineers who say, "If A works well and B works well, if I mix A and B together, it'll do a great job." This makes life exciting."
>
> Dr. David Parker, Santa Clara Fire Department

Because modifications to equipment or processes can affect other users, they are not allowed without permission from the Supervisory Committee. Remember that scaling up processes in volume/size will change the dynamics of the reactions and therefore the safe operating parameters. (i.e., more solution volume = less surface area for heat dumping. Improper mixing can cause superheating and explosions in a system believed to be well known)

Qualified users are the people who make the NSFL a dynamic, stimulating, and safe place to be. Any ideas regarding changes to policy that make the facility safer, cleaner, easier to use, or less expensive will be appreciated. There are "Comment" sheets available in gowning for this purpose. Qualified users are also encouraged to help those with questions, and to remind people of safety and cleanliness policies if they notice infractions. Please write up No-fault Incident Reports so any needed changes can be communicated. The safety and success of all in the lab is often that of the least attentive user.

Equipment/Processes Which Have Qualified User Requirements

Emergency response/ Chemical spill clean-up (ER/CSC)
Standard lithography
Negative resist lithography
Pressure washer
Standard etching (piranha, HF, metal etches, KOH)
Electroplating
Plasma etching
XeF_2 etcher
Sputter systems
Thermal evaporator
PECVD system
Thermal oxidation furnaces
Annealing furnace
Microscopes
Alpha-step profiler
Nanospec
FLX-2320 stress measurement system
Photomap 3D profiler
Direct bonding
Wafer saw

GENERAL POLICY

Booking equipment

Equipment can be booked for up to 3 hours at a time. Clipboards with booking sheets are on cinder block lab wall just before the vinyl curtain. Equipment can also be booked in advance, but you will lose the slot if you are more than 15 minutes late. At the end of an advanced booked slot, you can re-check the clip boards and re-book the room/process for another three hours if no one is waiting. If someone is waiting for the equipment, and you run over your time slot by more than 15 minutes, you will be disciplined. If you have finished your processing earlier than expected, please strike out your name from that time slot so others know they can use the equipment.

Equipment logbooks

The logbook for each machine must be filled out completely at each use. These records are maintained for reference regarding process parameters, history of materials used, use history for maintenance, communication between users, and for assessing fees.

Reporting problems

If something is not working as expected, please do not attempt repairs unless you have been assigned to do so by the Supervisory Committee. Inform one of the staff, and fill out a maintenance request form. These are available in gowning.

Lab Cleaning

The Lab is very large and requires regular cleaning if the class 10 target is to be met. On Friday afternoons, some processing will be disallowed, and constant users (those who are in the Lab more than 3 times per week) will be assigned cleaning tasks. Most assignments can be completed within an hour, and alternative arrangements can be made for those with prior teaching commitments. No-shows and assignments that are poorly done can result in a 2 week suspension from the lab.

SAFETY POLICY

Chemicals we have in daily use

Some of these are more nasty than others, and whether you will be using them personally or not, they will be around you. We expect you to be very familiar with this list.

Chemical name	Molecular formula	Uses	Characteristics	Hazards
Organics				
Acetone	CH_3COCH_3	Removes photoresist and Crystal Bond	Flash point - 17°C density 0.79	-extremely flammable -explodes on contact with piranha solutions -skin absorbable poison
IPA (Isopropyl alcohol)	$(CH_3)_2COH$	cleaning solvent	f.p. 11.7°C density 0.79	-flammable -do not inhale fumes
Hexane	C_6H_{14}	cleaning solvent	f.p. -22°C density 0.66	-extremely flammable -do not inhale fumes
HMDS	$[(CH_3)_3\text{-}Si\text{-}]_2\text{-}O$	Surfactant to bond photoresist to oxide	f.p. –3.9°C density 0.76	-binds to moisture in lungs, preventing O_2 exchange
Methanol	CH_3OH	cleaning solvent	f.p. 12 density 0.8	-toxic vapour, causes blindness -very flammable
Acids				
Hydrochloric	HCl	aqua regia iron getter	conc. 36% density 1.2	-fumes in air and causes severe burns
Nitric	HNO_3	chrome etch glass etch	conc. 95% density 1.5	-decomposes violently in alcohol, -extremely corrosive oxidizer
Hydrofluoric	HF	glass etch	conc. 49% density 1.15	-invasive corrosive -fumes cause severe damage
Sulfuric	H_2SO_4	acid piranha	conc. 98% density 1.84	-very exothermic rxn. when mixed with water -extremely corrosive oxidizer
Acetic (Glacial)	CH_3COOH	aluminium etch	conc. 36.8% density 1.10	-flammable -do not inhale fumes
Phosphoric	H_3PO_4	aluminium etch	conc. 85% density 1.68	-irritates mucous membranes
Bases (Alkalis)				
Ammonium hydroxide	NH_4OH	base piranha	conc. 28-30% density 0.9	-corrosive -induces tearing
Potassium hydroxide	KOH	developer , Si etch	Absorbs water from air	-corrosive
Sodium hydroxide	NaOH	developer , Si etch	Absorbs water from air	-corrosive
Oxidizers				
Hydrogen peroxide	H_2O_2	acid piranha	conc. 30%	-causes organics to burn -decomposes into H_2 + O_2 gas -keep in vented containers
Iodine	I_2	gold etch		-vapour is toxic and corrosive

There are two particularly dangerous chemicals in daily use in the lab that warrant more attention; piranhas, and hydrofluoric acid in any concentration or form.

Piranhas

A piranha is a solution used to remove organic residues from substrates. There are two different types. The most common is the acid piranha, a 3:1 mixture of concentrated sulfuric acid with hydrogen peroxide. People working with quartz substrates also use a base piranha, a 3:1 mixture of ammonium hydroxide with hydrogen peroxide. Both are equally dangerous when hot, although the reaction in the acid piranha is self-starting where the base piranha must be heated to 60 degrees before taking off.

There are many things that will cause the reaction to accelerate out of control. "Out of control" can mean everything from piranha foaming out of its container and on to the deck and floor, to an explosion with black acrid clouds of burning gases and a huge shock wave turning any glass in its path into shrapnel.

Please note:

- Even cool piranhas can explode on contact with acetone.
- Peroxide + solvent= oxidizing agent + reducing agent = vigorous combination.
- Piranhas remove organic RESIDUES ONLY.

If you add fuel to a piranha, it will accelerate. Fuels include:

- water (both types of piranha contain water-reactive chemicals)
- photoresist (is a base)
- nylon holders or chucks (usually from spinner/developer systems)

Using acetone in the Wet Etch module is forbidden. An instance of "forgetting" can result in being banned from the lab. (Acetone processing is to be done on the wet deck in Litho.) If somehow any quantity of acetone does end up in a piranha, don't look at it, don't try to fix it — just get out. Processing with alcohol-based solvents like IPA on the piranha deck is forbidden. They should be used on wet deck #2.

The hydrogen peroxide in piranha continues to decompose into oxygen gas long after the solution is cold. Never store a piranha, not even in a vented bottle. When no longer of use, an ER-CS qualified user will aspirate the piranha into the bottom of the wet deck while the plenum flush is operating and the trap closed. After this dilution, the chemical is neutralized before disposal.

HF/BOE

The F^- ion is the only thing that etches SiO_2. It is used to remove contaminants from Si wafers ("RCA Clean 2"), pattern the oxide when building devices, and to etch glass. BOE is labeled with the ratio of buffer to free F^- ion. Please note, BOE is just as concentrated as "pure" HF solution, as the buffer instantly replaces any free F^- ion used up (by an etch, your body) with another.

At low concentrations, HF is a neutral molecule that passes through the protective layer of the skin. When it disassociates, the H^+ ions cause deep tissue chemical burns and F^- ions bind to the calcium in cell walls and the bloodstream. CaF_2 is insoluble. When it precipitates, it lysis (bursts apart = kills) those cells. One of the most common effects of an HF burn is the development of gangrenous tissues. Because lower concentrations of HF do not cause an immediate burning sensation on contact like other acids, damage can be extreme and irreparable as the exposure goes unnoticed by the user. In high concentrations, the greater availability of H^+ does cause surface chemical burns in addition to deep tissue disruption.

The body uses the ratio of Ca^{2+} : K^+ as a controller. When the Ca^{2+} removed from the system by binding to the F^- (too little=hypocalcemia), there is too much K^+ (hyperkelemia). Potassium concentration regulates the electrical impulses to the heart. Untreated exposure to HF can lead to irregular beating, then heart attacks.

Pure HF is an acrid, extremely toxic gas. The version we use in the lab is this gas dissolved in water with concentrations up to 49%. HF (gas) dissolves into water easily, and it comes out of water easily. Only use HF solutions at the back of properly operating wet decks. Spills on the floor immediately constitute an extreme danger to anyone in the room. Breathing in HF vapour causes a build up of fluid in the lungs (pulmonary edema) and leads to respitory failure. If HF gets in your eyes, you can expect to lose your sight.

DRESS IN THE APPROPRIATE CHEMICAL GEAR WHEN USING THESE, AND OTHER CHEMICALS IN THE LAB. PROPER GEAR TURNS AN ACCIDENT WHICH WOULD HAVE BEEN LIFE ENDING INTO A SITUATION WHERE THERE IS ONLY A MESS TO CLEAN UP.

What is an MSDS, and how it is used

MSDS stands for Material Safety Data Sheets. They contain all the information governments have deemed necessary for anyone working with the chemicals to know. An MSDS must include: the manufacturer's name and address, the "legal" and common chemical names, physical properties, hazards to human health, and what to do if there has been an accident.

The white binders with the red labels on the safety desk in Room E3-450 contain the inventory list for every chemical we have on site in alphabetical order, followed by the complete MSDS. Anyone using a chemical should read the MSDS sheet first.

MSDS's use language that most non-safety officers are unfamiliar with. The following definitions should help in you understanding what you are reading. They are an amalgamation of definitions found in:

- "MSDS HyperGlossary" by Rob Toreki of Interactive Learning Paradigms, Inc. at http://www.ilpi.com/msds
- "Policy of Safety and Environmental Compliance Appendix "D", University of South Alabama, http://www.southalabama.edu/environmental
- "Stanford Nanofabrication Facility Manual, part II, section 5.1", http://snf.stanford.edu/Safety/Safety.html
- "Chemical Burns" by Robert Cox, MD, Ph.D. at http://www.emedicine.com/EMERG/topic73.htm

Acid / Base: Acids are defined as proton donors (H^+), and bases are defined as proton acceptors (OH^-). (A base is often described as an alkali) The strength of an acid is defined by how easily it gives up the proton; the strength of a base is determined by how avidly it binds the proton. The strength of acids and bases is defined by using the pH scale, which ranges from 1-14 and is logarithmic. A strong acid has a pH of 1 (e.g. sulfuric acid), and a strong base has a pH of 14 (e.g. NaOH). A pH of 7 is neutral. In contact with human flesh, most acids kill cells by denaturing proteins, forming a coagulum (e.g., eschar) that limits the penetration of the acid. Bases produce a more severe injury known as liquefaction necrosis, where fats in the cell membranes are turned into soap ("saponification") while the cell proteins are denatured. This process does not limit the tissue penetration of the base. Hydrofluoric acid is somewhat different from other acids in that it produces a liquefaction necrosis.

Caustic / Corrosive: Any strongly acidic or basic material that burns, irritates or destructively attacks living tissue. Splashes in the eyes can cause blindness. Inhalation of vapours can destroy lung tissue. Corrosives in the lab include the following chemicals and their mixtures:

Caustic / Corrosive:(continued)

Acids — sulfuric, nitric, acetic, hydrofluoric, buffered oxide etch

Bases — potassium hydroxide, tetramethyl ammonium hydroxide, developer solutions

Oxidizer: A chemical that causes other substances to lose one or more electrons. They can spontaneously evolve oxygen at room temperature, and can explode when shocked or heated. (oxidizers grab the electrons off of other chemicals). When mixed with compounds such as solvents that can act as reducing agents, (chemicals which like to give away electrons), the result is a vigorous, possibly explosive, reaction. The most noticeable oxidizer in the lab is hydrogen peroxide, but the oxidizing acids (sulfuric, nitric, acetic and others) are oxidizers as well as corrosives.

Organic: Any chemical compound containing carbon and hydrogen.

Boiling Point: The temperature at which the vapour pressure of a liquid is equivalent to the surrounding atmospheric pressure, and the liquid rapidly becomes a vapour.

Flammable: Any liquid having a flashpoint below 100°F (37.8°C)

Flashpoint: The temperature at which a liquid (or volatile solid) gives off vapour in quantities significant enough to form an ignitable mixture with air**.** The vapours can travel over considerable distances. (The source of ignition can be far away from the flammables container itself.)

Flammability: The ease with which a liquid, solid, or gas will ignite, either spontaneously (pyrophoric) or as the result of a spark or an open flame. The more flammable a material, the more readily ignition occurs. Flammable liquids themselves are not flammable; rather, the vapours from the liquids are. Flammables in the lab include acetone, IPA, and methanol, and acetic acid and photoresist to a lesser degree. Know the flash point of any material you work with. Minimize hazards by placing your set up at the back of the deck where the air pulled in keeps the concentration of vapours below the flash point. Always note the location of the nearest safety shower and fire extinguisher.

Water reactive: Water reactive is used to describe compounds which generate heat and/or gas upon mixing with water. Incomplete mixing leads to superheating and explosion. When making solutions, the water-reactive compounds are added to the water slowly, and thoroughly mixed while pouring. Compounds include concentrated acids, (sulfuric, nitric, acetic) and bases (potassium hydroxide, TMAH).

Carcinogen: A chemical capable of causing abnormal and uncontrolled cell division. (cancer)

Mutagen: Chemical compounds or physical forces (RF) that induce mutations in DNA and living cells such that the mutations are passed down to future generations. Both male and female germ lines are equally affected. (These chemicals mutate the cells in the process of becoming sperm or eggs.)

Teratogen: Chemical and physical agents which interfere with normal embryonic development. Teratogens may produce congenital malformations or death of the fetus without damaging the lady who is pregnant.

Toxic: A toxic material has poisonous or harmful effects to living animals. Formal, quantifiable definitions as to what is a toxic material are based on observed lethal dosages for lab animals.

Acute toxicity: The ability of a substance to cause severe biological harm or death soon after a single exposure or dose.

Sensitizer: A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical. (latex = natural rubber)

PEL: Permissible Exposure Limits for the work place. The limits can be based on TWA (time weighted average) or maximum concentration per exposure.

TWA: Time Weighted Average is the concentration for a normal 8-hour working day (40 hours/week) to which all workers may be exposed without adverse effect.

TLV: Threshold Limit Value indicates the concentration of a chemical substance in the atmosphere that is considered non-hazardous in a person's normal working life.

STEL: Short Term Exposure Limit is the average concentration to which workers can be exposed to for a short period (usually 15 minutes) without experiencing irritation, long-term or irreversible tissue damage or reduced alertness. The number of times the concentration reaches the STEL and the frequency of occurrences can also be restricted.

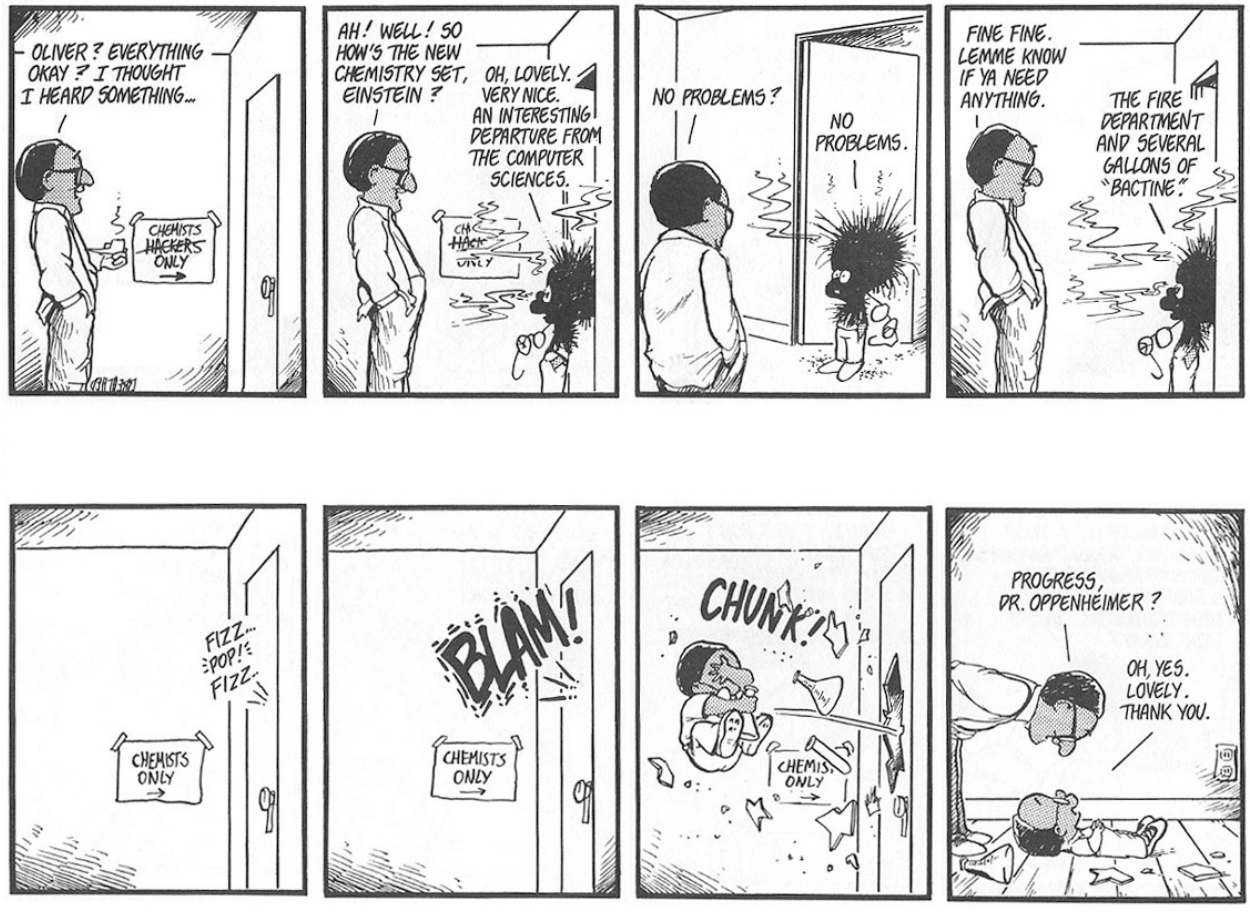
Ceiling (C): The concentration of exposure that should not be exceeded at any time.

LD50: The quantity of material that when ingested, injected, or applied to the skin as a single dose, will cause death of 50% of the test animals. The test conditions should be specified, and the value is expressed in g/kg or mg/kg of body weight.

Other sources of information

The Merck index, CRC handbook, and Aldrich catalogue are all good references. Aldrich has chemical formulas, molecular weights, a brief safety description, and prices. The Merck index has lots of good health and incompatibility information, but concentrates primarily on organic, not inorganic chemicals. The CRC handbook has most physical constants you can think of, (densities, melting points, vapour pressures, defined units...) provided you can find where in the 1500 page book they are.

People unfamiliar with the basic properties of chemicals and needing more information are encouraged to find any first year chemistry textbook. The ones by S. Zumdahl, or D. McQuarrie and P. Rock are well written.



from Berkeley Breathed's "Bloom County"

Working in the Lab

Standard NSFL chemicals versus special project ones

The inventory of chemicals that can be used at the NSF lab is in the front of the MSDS binders on the safety desk in the lab. If you wish to bring in more of the same, obtain permission from the Lab staff to ensure adequate room for safe storage.

If the chemical has not been previously used, fill out a Chemical Import Form accompanied by at least 2 versions of the MSDS. MSDS's can be obtained from the chemical supplier, or internet sites such as:

http://www.setonresourcecenter.com/MSDSs/com
http://www.anachemia.com/engnew/frame/ressource1.html
http://hazard.com/msds/index.php

The Supervisory Committee will determine if the chemical can be used safely in the existing facilities. As a note, at this time, no mutagenic or teratogenic chemicals are allowed in the NSFL.

Where the chemicals you need are stored

Stock chemicals are available in the Fab for all users. Photoresist and developer solutions are kept in Litho on the wire rack. Acids are kept in Wet Etch in the cabinets, and solvents and hydrogen peroxide are kept underneath the wet decks. Remove the amount of solution you need for your set-up from these stock bottles, and make a secondary bottle for your own personal use. Never use a stock bottle as your own, as you will contaminate the bottle for the next user. (Yes, this even applies to solids) Find an appropriately sized Nalgene bottle, then label it using a permanent ink pen with:

- Your name (first and last)
- Exactly what is in the bottle (i.e., not "glass etch", but 10% HF, 5% nitric, 85% water)
- Date the solution was made

These labels must be legible. If time or use has made them hard to read, strip the first label with IPA or acetone and re-write it.

Because space is at a premium, only one stock bottle of each chemical will be stored inside the Fab. If the volume of chemical left is too small for your needs, call a staff member and they will bring another bottle from storage. Use up the older bottle before opening the new one.

Setting up

The first time you do any wet chemical process, you should test your arrangement of beakers, substrate holders/boats and stir bar to make sure all the pieces fit and work together the way you expect. Fill the set up with DI to discover the minimum volume of chemical you need to cover the substrates. Ensure the chemical you are pouring in the labware is compatible with it. HF dissolves glass beakers, some organic solvents digest plastic. Use extreme caution when heating solutions on hot plates. (Glass beakers only, Teflon and plastic melt.) Always monitor the temperature of the solution with a Teflon coated thermometer. Special permission from the Supervisory Committee is necessary before any solvent can be heated.

Up to two people can use a deck in wet etch at a time, provided they are running similar processes, (both using acids, both using organics, etc.), with the following caveats:

- Piranhas must be done on deck 1.
- Alcohol based solvents (IPA, methanol) must be used on deck 2.
- Acetone is only allowed on the wet decks in Litho.

Anisotropic etching of silicon is done on the wet decks outside the cleanroom.

Liquid chemicals should only be dispensed on wet decks. Note: When pouring chemicals, make sure you only have 1 bottle open on the wet deck at one time. This minimizes cross contamination in case of a spill, and also ensures you put the correct screw cap on the correct bottle.

Labeling

The beakers and trays you use for your processing must be labeled with the same things as your chemical's storage container (name, contents, date). Because the dark colour of photoresist and gold etch make penned labels difficult to read, these chemicals can be placed on a labeled cleanroom wipe.

If your process is such that the set-up remains overnight, you also must include:

- Time you are coming to clean up
- Telephone number('s) where you can really be reached (where you are eating, sleeping)

Orphan beakers with unknown contents are the second most common cause of chemical accidents in a lab. Don't assume that standing beside the container is enough. You can get called away to answer the phone, or have to leave the room to attend to substrates in another part of the Fab. These will be disposed off as hazardous waste immediately upon discovery, and disciplinary action taken.

Gowning for chemical hazards

Safety glasses must be worn in the Fab. Goggles offer better protection, but their use is optional as some users have trouble with them fogging when worn for long periods of time.

Wet chemical processing areas have the following additional safety gear:

- Coat apron. This purple/blue vinyl apron with sleeves is put on first. It protects your arms, torso, and legs to the knee.

- Face shield. This goes on second, over the glasses to protect your face and throat, and to increase protection for your eyes.

- Chemical gloves. The nitrile bunnysuit gloves are worn to protect the lab from you. You must put on Silver Shield (grey), Butyl (black), or TRIonic (tan) overgloves to protect yourself from the lab. Test these gloves weekly to ensure there are no holes by inflating with N_2, and then immersing them in water. If you see bubbles, get new gloves. Overgloves, as the name implies, go OVER the blue nitrile gloves, and OVER the sleeves of the coat apron.

All four pieces of safety gear must be worn while:

- dispensing chemicals at the beginning of the set-up
- making up a new solution mixture
- pouring the chemicals back into the storage container after processing is done
- rinsing emptied stock bottles

After the set-up is complete, the user can chose to remove the faceshield, coat apron and chemical gloves.

NOTE: The coat apron and overgloves must continue to be worn when processing with:

- piranha
- HF-BOE
- heated etchants

Please feel free to continue to wear face shield; it is cumbersome, but offers the best protection.

If you notice spots of chemical on your gloves, rinse them off in the foot-operated dumprinser. Chemical spots on your apron should be wiped off with a cleanroom wipe which is then rinsed out to make it safe for disposal. These actions prevent a chemical from sitting on the safety clothing and eventually working its way through the fabric to expose the wearer.

Take off the chemical overgloves BEFORE touching anything that could be touched by a person wearing only the nitrile gloves. This includes the spin rinse dryer, phone, door handle, and permanent ink pens. (i.e., rinse them well, dry them, then take them off.)

Note: If using large quantities of acetone in the Litho module, overgloves should be worn in addition to the standard bunnysuit gloves as acetone goes right through nitrile.

Cleaning up

People will respect you more if you leave the work area better than you found it. The clean, dry labware on the rack should be put away to make room for your stuff. Put on all the safety gear. Pour the chemicals in the labware back into your storage containers carefully, completely, and one at a time so you only have one opened bottle sitting on the deck. Stock and personal storage bottles should be rinsed off, dried, and put back in the proper storage locations. REMOVE the LABELS from your beakers. Mislabeled contents in beakers are the primary cause of lab accidents. This happens more often when people put "clean" labware back in the drawer with a label still on. Dirty labware and emptied stock bottles are to be washed according to one of the three washing procedures depending their original contents.

1) Contained acids / bases / oxidizers (H_2O_2)

Rinse these chemicals with water on wet deck 1 (the piranha deck). Start the plenum flush to dilute the chemical rinsed off the sides.

1st rinse	- fill container ~80%, invert, and drain completely
2nd, 3rd rinse	- wash down sides of container and drain completely
4th, 5th rinse	- needed for anything with HF

Remember to rinse off the caps from the stock bottles. Clean, delabeled labware is placed on the drying rack. The label of a washed stock bottle is defaced, and a stick-on " rinsed" label placed over it.

2) Contained water miscible solvents (IPA, acetone, methanol, alcohol)

Invert the labware or stock container on a cleanroom wipe at the back of the deck until dry. usually 10 min.) Rinse three times with water on wetdeck 2 (the non-piranha deck in wet etch). Delabeled labware goes on the drying rack; stock bottles labels are defaced and relabeled as "rinsed".

3) Contained photoresist, halogenated solvents, or metal ions (e.g. chrome, gold, or aluminium etch)

Stock bottles which contained any photoresist, metal etch, or a solvent with a halogen as part of its structure, (halogens = chlorine, bromine, iodine) are considered hazardous waste and are not rinsed. Inform the lab staff, and they will remove the bottle and store it for disposal by EH&S.

Labware contaminated with photoresist or halogenated solvents are rinsed 3 times with acetone. These rinsings are then discarded into a waste bottle which has been labeled to accurately describe the contents. Labware contaminated by a metal etch are rinsed three times on the wet deck with the plenum flush running.

Once they are rinsed, stock bottles are placed outside the module doors to be collected by the staff. Dead etchants, (those whose etch rate is half of the expected because the active component is exhausted) must be given to the staff for proper disposal by EH&S.

After your labware is rinsed and hung up to dry, the deck should be rinsed down, starting from the front and working to the back. Chemical overgloves need to be rinsed, dried, put back in your zip lock bag, and removed to your storage bin. Pens go back in storage, and loose notes are taken out of the room. Note any equipment or process problems in the log books, and fill out maintenance request forms. Any wafers that are junk, as well as broken wafers or glass substrates are disposed of by putting them into the container labeled "Sharps" -broken Si and glass. Do not put these into the regular garbage, you could hurt someone. After leaving room E3-450, make sure you wash your hands with soap and water.

Accidents

Your health is the primary concern. Your device, the lab particle count, or floor puddles are IRRELEVANT; someone else will deal with them.

Your Safety Buddy is your backup. They call 555 and tell Campus Security that:

- there has been an accident in E3-450, the Nano Fabrication lab.
- the accident involves ___"X"___ equipment / process / chemical.

Note: Do NOT call 911. Ambulance people have no idea where the lab is, and they don't have keys to get in anyway. Campus Security people are often ex-paramedics, bringing immediate medical help, and they co-ordinate all other emergency personnel.

If you need help and no one is coming, accidents are broken down into two groups:

- equipment based injuries - obviously, call loudly for help, and if no one comes, phone 555 yourself.
- chemical based injuries - Get rinsing. If you were foolish enough to process without a safety buddy and no one has noticed your accident, call for help on 555 only AFTER all the required rinsing is done.

Accidents involving chemicals

With a chemical splash, you want to remove the bulk of the chemical as quickly as possible. If the eyes or an extremity like a hand or foot is involved, the fastest, closest source of water is the DI on the deck (from gun, dump rinser, gooseneck). Start rinsing, then peel off the bunny suit and affected clothing. In an eye splash, move the 10 ft to the eye wash station on the acid shower as soon as you can. Its gentle, crisscrossing streams of water will clean out the chemical more effectively without recontaminating one eye with the solution washed from the other, or causing pressure damage. (Harsh streams of water may drive chemicals further into the eyes) Hold eyes open with thumb and forefingers. Ensure chemical trapped behind the eye is removed by rolling the eyes continuously up and down, side to side. Occasionally lift the upper and lower lids away from the socket. Do not apply an acid or base neutralizing agent in the eye under any circumstances. A film of denatured eye protein will develop and trap the basic (pH 8-14) chemical BEHIND it, making it inaccessible to rinsing.

Note: if a chemical has splashed your face but not your eyes because you were wearing goggles, DON'T TAKE OFF THE GOGGLES UNTIL RINSING IS FINISHED. If you were wearing contact lenses under the goggles, after the rinsing is finished and after removing the goggles, take out the contacts and rinse the eyes as a further precaution.

For torso or large area exposures, get to the shower. Start the rinsing, then GET OUT OF YOUR SHOES AND CLOTHES. Modesty could kill you. We have hospital-type scrub suits in all sizes to put on for the trip to the hospital. In all cases, remember to use the nail brush to remove chemical trapped under and around the nail. Burns are very common in this area because the person thought they had rinsed enough, yet residue remained.

The length of time to rinse depends on the chemical involved and area of contact.

HF Accidents - exposure to skin

Rinse for a MAXIMUM OF 5 minutes.
Liberally apply, then massage in, calcium gluconate gel.

There should be significant pain relief within 30 minutes. Continue applying the gel intermittently for two hours. (Wear overgloves on unaffected hands to protect them while applying gel) White specks around the burn mean the antidote is working. This gel functions as a getter for the F- ions and will even work for deep tissue damage. There are tubes of gel in wet etch and in the safety supply cabinet. There are also tubs of gel available in the safety cabinet for larger exposure incidents.

If the exposure was small, (drops) or only suspected, (something hurts and you don't know why) take a tube home with you in case the pain re-appears. It is usually not necessary to seek further medical attention in these cases. There are three situations where you MUST seek additional medical attention at either the University Health Centre or the Misericordia Urgent Care Centre.

- any burn which has failed to respond to treatment within 30 minutes. (i.e., there has not been a significant relief of pain within that time)
- burns which have blisters or the appearance of whitish or dead skin.
- burns which involve large exposures. (more than 5 x 5 inches)

Make sure the gel goes with you as you are transported to the medical facility. Take copies of the Honeywell and emedicine reports (found in the safety cabinet) as the emergency room doctors may not have any familiarity with managing HF burns. Make sure they understand that HF isn't just another acid.

HF Accidents - exposure to eyes

Rinse for at least 5 minutes.
Repeatedly irrigate eyes with syringes filled with sterile 1% calcium gluconate solution.

This requires the assistance of others. If help has not yet arrived, continue the water rinsing for at least 15 minutes. You must seek further medical attention in ALL eye exposure cases. Go to the

Misericordia as it is the eye trauma center for Winnipeg. Ice water compresses can be applied while transporting to the hospital.

All other Chemical Accidents

Rinse a MINIMUM OF 15 minutes for ANY exposure.

For acids or solvents, rinse until there is no more burning sensation. For bases, rinse until the skin no longer feels slippery. Rinsing can take up to 45 minutes. Follow-up with medical attention.

After the crisis has past, No-fault Incident Reports have to be filled out by everyone involved. (witnesses, helpers, victims, clean-up crew) If there has been an injury, the green "Notice of Injury" card must be filled out and given to the Occupational Health Co-ordinator at EH&S. If any work time is lost due to an injury, a Worker's Compensation Claim should be started.

What the safety buddy or person arriving on the scene of a chemical accident does

First priority:

Help the victim AFTER ensuring you are properly equipped. This can range from putting on chemical resistant gloves to getting into full gear including safety booties, coat apron, goggles, face shield, and gloves. We don't need two victims for the price of one. If the exposure was small, the only help you may need to give is reminding the victim of what to do, or in the case of HF exposure, fetching the HF gel. If the chemical exposure was large enough to require the use of the safety shower, don't enter the shower area when the victim first starts their decontamination as there may be enough chemical diluted in the shower water to pose a risk if it splashes past your protective equipment. If the victim is having trouble removing/cutting off their contaminated clothing, momentarily interrupt the shower to quickly help them. After the victim has showered for a minute unclothed, there should not be enough chemical in the splashes to pose a hazard. (The use of the shower at this point is to remove the chemical residue adhered to the skin or eyes. Also please note: If the drain cannot keep up with the shower, there will be diluted chemical in the puddle on the floor beside the shower. Anybody standing in it had better be wearing the "Silver Shield" chemical booties.) If someone is already helping the victim . . .

Second priority:

Contain the situation at the accident site to minimize the harm to others. Grab a few of the yellow chemical spill pads and place them at the edge of any chemical spilled to prevent it from going down a

drain. (1 pad soaks up 3.3 liters of solution) Mark the spill location, or stand guard outside the door to warn others. Once the spill is identified . . .

Third priority:

Notify the staff of the accident. They will decide if external resources are needed to help deal with the situation. If no staff member is available, call 555. NOTE: ONLY PEOPLE QUALIFIED IN EMERGENCY RESPONSE ARE ALLOWED TO NEUTRALIZE AND CLEAN UP CHEMICAL SPILLS.

Forth priority:

If everything has been attended to, leave. You could be making things worse by being in the way.

Fire

Small organic fires can be suffocated by covering them with inverted beakers. If you know how to use a fire extinguisher, you can attempt to put out a small open fire which is not spreading beyond its point of origin. Always make sure there is an exit at your back so you can get out if you need to. Get close enough to the fire for the extinguisher to work. (within 10 ft for a CO_2 extinguisher, and 6 ft for a dry chemical one) Aim at the base of the fire, and move across the fire from one side to the other. You are herding the flames to a place where there is no fuel. If you are not confident about your ability to put out the fire, you are under no obligation to try. Leave the cleanroom in your bunnysuit by the nearest exit into the chase. Isolate the fire by turning off the HEPA fans to that module. Call 555 to notify Campus Security AFTER you are safely out of the module. If the closest outside door on your evacuation route is the one next to the ID board, remove your card so the hazard response team has one less person to be concerned about.

If someone has caught fire, get them to cover their face with their hands and Stop, Drop, and Roll. Other helpers can run to get the fire blanket and BRING IT TO THE VICTIM. The safety shower is a possibility only if the person is very close to it. Roll, don't run. Do not spray the victim with a fire extinguisher, you could suffocate them with the chemical. Call 555 with the lab's location, and tell them someone has caught fire. Keep the victim's burned areas clean and dry. (Don't remove clothing or irrigate the burn with water in cases of 2nd and 3rd degree burns or where the burns cover a large extent of the body.) Cover the burned areas with sterile non-stick pads from the first aid kit. Elevate the victim's legs to ward off shock, and try to keep the victim calm.

The treatment for the more common small burns, (such as those developed when the skin comes into contact with something hot like a hot plate), is to cool the area with water (never ice) and to apply an antibiotic ointment like polysporin. Watch for signs of infection.

If the fire is big enough that it may pose a danger to the whole building, pull the fire alarm. Leave the cleanroom in your bunnysuit by the nearest exit to the chase. Isolate the fire by turning off the HEPA fans to that module. Leave by the hallway door. Phone 555, and tell campus security the location of the fire so they can co-ordinate the emergency services. Leave the building by the nearest exit.

Accident and Fire Prevention

The main way to prevent small problems from blowing up into major accidents is to deal with them quickly in a non-threatening manner. The no-fault incident report exists for this reason. As the name implies, penalties will not result from incidents reported on these forms. Reports should be filled out if a user notices:

- instances of unlabeled beakers
- a chemical spill (including, of course, the one you yourself caused)
- electrical shocks
- other users not following policy

If there is an injury accident, a "Green Card Injury" form must be filled out and given to the Occupational Health Co-ordinator at EH&S. If there is an injury accident where time off work is needed to recover, Manitoba law requires the injured and the employer to fill out Workers Compensation forms.

Any new safety policy that is generated in response will be posted on the safety cabinet, and sent to all lab users via e-mail.

Right to refuse unsafe work

Every person in a work environment has the legally protected right to refuse unsafe work without penalty. This does not mean you can choose to do a M.Sc. where capillary channels are etched in glass and then refuse to use HF solutions. (You have chosen to work in an area that has "inherent dangers") It does mean however, if there is a funny smell in wet etch, or an unlabeled beaker and a puddle on the floor, you do not have to work even if your supervisor has said "I expect you to have this done by tomorrow or else".

How much things cost

People are much more careful when using equipment and materials when they know how much it would cost them to replace it. To that end . . .

Plasma etcher		$300,000
Mask Aligner		150,000
Sputter system		150,000
Sputter target		2000+
Sputter run, precious metal		200
Sputter run, cheap metal		100
HMDS oven		70,000
Alpha step		80,000
Alpha step needle		1,000
Turbo pump		30,000
Wet deck		30,000
Photoresist/developer spinner		20,000
Soft bake oven		18,000
100X objective	(each one)	9000
HEPA filter	(each one)	1000
Piranha bin	(quartz)	2000
	(teflon)	500
XeF_2	(canister)	3000
Photoresist	(1L bottle)	1500
HF	(4L bottle)	320
Sulfuric acid	(4L bottle)	86
Acetone	(4L bottle)	25
IPA	(4L bottle)	25
Teflon boat		200
Wafer carrier + carry box		70
Wafer tweezer		35
Cleanroom wipes	(package)	17
Tantalum boat		25
Tungsten boat		20
Molybdenum boat		10

Penalties

We hope this document gives enough background information that any person can easily see the reason behind every policy, and the requirement to follow them absolutely. Unfortunately, unreasonable people exist.

1st offense:

Unless the abuse was obvious and flagrant, we will assume the user was unaware of the policy, train them very, very well, and make the lab inaccessible until re-training is completed. Your supervisor will be informed.

2nd offense:

Normally a suspension of 6 months after which the individual meets with the Supervisory Committee to make a case for re-instatement. Users who open the doors to allow access to someone suspended from the lab will usually be disciplined at this level.

3rd offense:

Automatic expulsion from lab.

Notes:

This policy is not meant for minor lapses in judgment of experienced uses or errors made when new users are in the lab the first few months. It is there to prevent incompetent or arrogant people from destroying hard-gained work, and from hurting themselves and others.

Flagrant disregard for safety or cleanliness can result in expulsion from the lab at any time.

APPENDIX

This section contains information that goes beyond what is necessary for you to know to enter the Lab safety. (i.e., not on the test) It is provided so the curious ones have more in-depth explanations, and so the rather specialized knowledge concerning the treatment of HF burns becomes widely known. It is possible that in encounters with emergency personnel or doctors, you will know more about HF hazards and treatment than they will. Copies of the reports mentioned in the HF section are stored in safety cabinet beside the emergency shower for anyone who wishes to read them, and for dispensing to responders of an accident.

Everything we know about HF

Three of the best sources of information about HF hazards and treatment are:

1) "Hydrofluoric Acid Burns" an Emedicine report found at www.emedicine.com/emerg/topic804.htm by Garry Wilks, M.D.

2) "Recommended Medical Treatment for Hydrofluoric Acid Exposure" by Honeywell, at www.honeywell.com/sites/sm/chemicals/hfacid/Tech_Services.htm. Under the heading "download technical documents", click on "HF medical book"

2) "First aid for a unique acid HF: a sequel" by Eileen B Segal, in "Chemical Health and Safety", Jan/Feb, 2000, p 18-23

The science behind the triple-rinse

Washing is actually a series of progressive dilutions. You can expect to remove 95-99% of the original liquid adsorbed on the container wall in any one rinse, providing the container is drained completely to avoid recontamination. With each rinse, there is another 95-99% exchange. Here is an example with a careful person washing a beaker with the weaker version of glass etch. (Weak glass etch is 20% HF stock by volume, 97% exchange)

rinse 1: concentration of solution adhered to side wall is 0.6% HF
rinse 2: 0.018% HF
rinse 3: 0.00054% or 5.4 ppm (parts per million) NIOSH TWL regulations are 3 ppm
rinse 4: 0.16 ppm = ~safe
Note: a concentrated HF solution or any BOE would need one more rinse to be safe

The labware is considered "washed" when so little of the hazardous chemical remains that a person touching the piece with bare hands would suffer no harm. For concentrated glass etch (HF acid) and any BOE, this means 5 careful rinses. For everything else, this means at least 3.

The dump rinser works as well as hand rinsing if the labware is loaded properly so that each piece drains completely between each cycle. If the labware doesn't completely drain, the old rinse water will recontaminate the new DI.

How we chose the overgloves we use

There are several different glove types in the lab.

1) Silver shield gloves, made of an "impervious to everything" grey plastic laminate, are available to everyone. They are the most resistant glove on the market, however, they are extremely difficult to use (awkward, slippery and binding).

2) The most common overglove in the lab is the tan TRIonic glove made of a natural latex / nitrile laminate developed especially for cleanroom use. They are inexpensive and very resistant, but are floppy, and can cause allergic reactions to wearers or even other users in close proximity.

3) Black butyl rubber gloves made of the same material as car tires. They are extremely resistant to HF, acids, bases, oxidizers, and acetone. (Note: butyl rubber and silver shield gloves are the only materials resistant to acetone) However, when exposed to organic substances like hexane, pump oil, or waxes, butyl rubber swells, becomes sticky, and leaves a black residue on whatever it touches. If you use these gloves when cleaning off machine oil or vacuum grease, put a large sized nitrile glove over the butyl one to make a "triple layer" sandwich. (The butyl rubber glove between nitrile ones.)

Why our shoe policy is different than what you expected

Back in the olden days when the first lab policy was written, most shoes were leather, and sandals where these teetery things women in dresses wore. Now however, there is no such thing as a leather running shoe (you try to find one). All are now synthetic, and all synthetic shoes have holes through them so the feet can breath. (Some have nothing more than plastic mesh on the top) Whatever protection used to be afforded by enclosed shoes no longer exists. (In fact the case can be made that modern shoes provide the wearer with a false sense of security as any chemical which does splash on the shoes goes though unnoticed until much damage has been done. Also, HF goes instantly through leather) Feet in a Fab are already completely enclosed in chemically resistant overshoes, and then further encapsulated in the overboots of the gown. Stability is the issue, not chemical resistance.

Supervisory Committee

Cyrus Shafai (Director)	Room E3-472	474-6302
Doug Buchanan	Room E3-559	474-9085
Doug Thomson	Room E3-455	474-8797
Greg Bridges	Room E3-411	474-8512
Derek Oliver	Room E3-444	474-9563